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Washington Observations, 1883; of Oberon and Titania, the outer satellites of Uranus, in 1881, Appendix i.; while in Appendix ii. he gives a determination of the orbit of the satellite of Neptune, and deduces the mass of Neptune. Finding that most of the measures of Hyperion had been made near one elongation, he made measures in 1875 and 1876 with the 26-inch, and computed an orbit. His mathematical papers were numerous, and covered most astronomical investigations.

Professor Hall had taken part in several observational expeditions, such as—the solar eclipse of 1869 (Behring Straits), of 1870 (Sicily), and of 1878 (Colorado); the transit of Venus of 1874 (Vladivostock) and of 1882 (Texas). In 1891 he retired from the Navy, and in 1896 he was elected to one of the Professorships of Astronomy at Harvard. His death occurred on 1907 November 22. He was elected an Associate of the Society 1879 Jan. 10. T. L.

Pierre Jules César Janssen was born at Paris on the 22nd of February 1824. He was descended from a family which originally dwelt at Liége. His father was a well-known musician, and his mother the daughter of an architect of some celebrity in Paris. An unfortunate accident when young, through the carelessness of a nurse, rendered him lame for life. The boy seems to have been endowed with considerable talent, which he at first exercised in drawing and painting. At the age of sixteen he entered into business as a clerk at a bank, in which he remained for seven or eight years, but during this period he devoted his spare time to the study of mathematics, which so absorbed him that he determined to quit business and to study science. He entered the Collège Bonaparte, and about 1850 took his degree as Bachelier-ès-Sciences. Subsequently at the Sorbonne he attended the lectures of Chasles, Cauchy, Lefébure, Le Verrier, and Sturm, and in 1852 received the degree of Licentiate of Mathematical Science, and later on that of Physical Science.

At the early part of Le Verrier's direction of the Paris Observatory, Janssen was with him as a computer; but the occupation not being very congenial to him, he did not long remain at the observatory, and for the next two years he became Assistant Professor of Mathematics at the Lycée Charlemagne.

In 1856 he made a tour in Turkey, Asia Minor, and Egypt, and in 1857–58 he undertook a scientific expedition to Peru to investigate and determine the position of the magnetic equator. In this he was assisted by his pupils Ernest and Alfred Grandidier. Unhappily he was seized with serious illness, from which he nearly died, and which compelled him to abandon the enterprise, and to sail for Europe to recover his health.

Soon after his return to France he commenced those researches that have made the name of Janssen illustrious in the domain of Solar Physics.

His first published scientific paper appeared in the *Comptes Rendus* for 1860, under the title "Sur l'absorption de la chaleur

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rayonnante obscure dans les milieux de l'œil," in which he showed the relative proportion of heat rays which are absorbed by the cornea, the aqueous humour, the crystalline lens, and the vitreous humour, and proved that only a small percentage of such rays reach the retina.

At this time the brilliant researches of Kirchoff and Bunsen had strongly attracted the attention of physicists, and Janssen determined to devote himself to some of the problems that had been indicated by spectrum analysis. In 1860 Brewster and Gladstone had demonstrated the existence of atmospheric bands in the solar spectrum. But so far back as 1832 the former had found that certain dark lines which were invisible with a high sun became conspicuous as it approached the horizon; and in 1856 Crookes had called attention to the fact that the atmosphere absorbed a great part of the more refrangible rays.

In 1862 Janssen established an observatory at Montmartre for the purpose of investigating the absorptive influence of the atmosphere. By means of a powerful spectroscope composed of five prisms he succeeded in resolving the dark bands into fine lines, which he found to vary in intensity directly as the altitude of the Sun, being darkest at sunrise and sunset. This established their atmospheric origin, and Janssen accordingly named them "telluric lines." The results were published in the *Comptes Rendus* for 1862.

In order to confirm these important observations he determined in 1864 to make experiments from the summit of the Faulhorn, when he was able to convince himself that the telluric lines were fainter there than at sea-level. Subsequently, at Geneva, on examining with the spectroscope the light of a bonfire at Nyon, a distance of thirteen miles, he at once perceived several of the telluric lines which he and others had observed in the spectrum of a low sun. Further researches on this point in 1866 enabled him to establish the fact that most of these absorption lines are produced by aqueous vapour.

In 1867 Janssen was sent by the Bureau des Longitudes to Italy to observe the annular eclipse of the Sun, his object being to make careful comparison of the spectra of the limb and centre of the Sun. As the light of the limb has to pass through a greater thickness of the solar atmosphere, it was expected that the absorption lines there would be strengthened, but the results obtained were purely negative.

In 1868 he was delegated by the Académie des Sciences and the Bureau des Longitudes to proceed to India to observe the total solar eclipse of August 18 in that year.

He was provided with four telescopes of 6 inches aperture with spectroscopes of different optical power, and he established his observatory at Guntoor. On mounting his instruments he found that the case of spectroscopes had been carried off by mistake and could not be available for the eclipse, but his foresight had provided one supplementary spectroscope, which was all he had at his disposal on the critical day.

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Several expeditions had been organised for this eclipse, for the purpose of making spectroscopic observations of the solar prominences. All were successful in observing bright lines in the prominence spectra, and thus establishing their gaseous nature.

In his report on the eclipse, Janssen wrote: "Pendant l'obscurité totale je fus extrêmement frappé du vif éclat des raies protubérantielles; la pensée me vint aussitôt qu'il serait possible de les voir en dehors des éclipses." Pursuing this idea on August 19, the day following the eclipse, he succeeded in making those memorable and historic observations which gave astronomers the new method of observing the solar prominences without the aid of an eclipse. With the slit of the spectroscope placed radially, partly on the Sun's disc and partly beyond, he swept a portion of the limb, observing the C line. His words are: "J'étais depuis peu de temps à étudier la région protubérantielle du bord occidental quand j'aperçus tout à coup une petite raie rouge, brilliante de 1 à 2 minutes de hauteur, formant le prolongement rigoureux de la raie obscure C du spectre Solaire. En faisant mouvoir la fente du spectroscope de manière à balayer méthodiquement la région que j'explorais, cette ligne persistait, mais elle se modifiait dans sa longueur et dans l'éclat de ses diverses parties, accusant ainsi une grande variabilité, dans la hauteur et le pouvoir lumineux des diverses régions de la protubérance."

Writing on September 6, 1868, he says: "c'est le 19 août que j'ai fait cette découverte, aussi la *véritable éclipse* a eu lieu pour moi le 19 et non le 18. Depuis j'ai pu tracer jour par jour la figure, la place, la composition des protubérances du Soleil visibles seulement jusqu'ici pendant les éclipses. Je lis dans un livre fermé jusqu'ici pour tous."

Janssen's report, dated September 19, was read at the meeting of the Académie des Sciences on October 26, 1868, and immediately following it was read a communication from the present Sir Norman Lockyer announcing his independent successful discovery of the same method of viewing solar prominences without an eclipse as that made by Janssen. The Académie des Sciences struck a medal in honour of the discovery, bearing the effigies of both astronomers, and the eloquent words of M. Faye on the occasion may be fitly quoted: "Mais au lieu de chercher à partager, et par conséquent à affaiblir le mérite de la découverte, ne vaut-il pas mieux en attribuer indistinctement l'honneur entier à ces deux hommes de science qui ont eu séparément, à plusieurs milliers de lieues de distance, le bonheur d'aborder l'intangible et l'invisible par la voie la plus étonnante peut-être que le génie de l'observation ait jamais conçue?"

The new field thus opened for the study of Solar Physics at once led the French Government to consider the question of establishing a suitable physical observatory for Janssen. The question was seriously delayed by the war, and it was not till September 1874 that the Académie des Sciences could report on the subject. A provisional observatory was first established at

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Montmartre, but eventually it was decided to utilise the Château de Meudon, where Janssen took up his residence in October 1876. In the meantime Janssen had undertaken several solar eclipse expeditions. In 1870, during the siege of Paris, he made his memorable escape in a balloon to observe the eclipse of December 22 at Oran, where the weather, however, prevented all observations. In 1871 he went to India and established himself in the Neilgherry Hills. He employed a specially constructed reflecting telescope, the mirror of which was 15 inches diameter, and had a focal length of only 56 inches. A direct vision spectroscope of ten prisms was employed. With the brilliant spectrum such an instrument gave he observed some of the Fraunhofer lines in the continuous spectrum of the corona, and was also able to determine that the green 1474 line in the corona was not visible in the spectrum of the prominences. He also went to India to observe the eclipse of 1875 April 6.

In 1874 he undertook an expedition to Japan to observe the transit of Venus.

In order to secure a photograph of the actual geometrical contact he invented the "Revolver Photographique," an instrument which takes a series of photographs at short intervals of time precisely on the principle of the cinematograph, of which it is indeed the forerunner.

It is from this period that those researches of Janssen's in solar photography date which have culminated in the remarkable "Atlas de Photographies Solaires," published in 1903. At the commencement of work at the Meudon Observatory, Janssen erected a special instrument for photographing the solar surface. It consisted of a telescope of 5 inches aperture, with a suitable enlarging lens which allowed him to obtain an image of the Sun from 12 to 18 inches diameter. In the optical construction of it he utilised the fact that there exists in the spectrum, near the Fraunhofer line G, a narrow band of rays which possess a photographic activity upon the salts of silver much more intense than that of any other portion of the spectrum; so that if the exposure be very short and properly regulated, the effect is practically the same as if the sunlight were monochromatic, consisting of these rays alone, and any defect in the correction for chromatic aberration in the lens is rendered almost harmless. With this telescope, and with exposures so small as from $\frac{1}{1000}$ to $\frac{1}{3000}$ of a second and even less, Janssen obtained that marvellous delineation of the solar surface which is so well known from the published results. He described all his methods in a very complete paper on the subject in the *Annuaire du Bureau des Longitudes* for 1879. The first significant discovery he was able to announce was that of the "Réseau Photosphérique," by which term he designated certain hazy, smudgy patches in the granular surface of the photosphere, which, in his opinion, showed continual agitation and change in the solar atmosphere. Employing this apparatus in photographing a partial eclipse of the Sun, he showed that not the slightest distortion

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in the solar granules could be detected up to the limb of the Moon, and by this most delicate test any evidence of the existence of a lunar atmosphere was completely negatived.

Though the Château de Meudon had been in a great measure destroyed by the siege of Paris, yet the stables, nearly 100 metres long, remained intact, and were formed by Janssen into a very suitable laboratory for the study of absorption spectra, the divisions of the stalls forming excellent supports to the lengthy tubes he employed.

Jules Janssen was endowed with great energy, courage, and determination, which in no case are shown more conspicuously than in the ascents he made of Mount Blanc for the purpose of making spectroscopic observations in the higher strata of the atmosphere. He made two ascents, in 1893 and 1895. His lameness prevented him from walking, and consequently he was carried by porters from Chamounix to the summit—a quite unique performance. But this enabled him to arrive at that high altitude with a mind and body unwearied by physical exertion, and thus able to devote himself under the most favourable circumstances to the observations he proposed to make, and also to plan out an observatory on the summit. One of his principal objects was to determine the presence or not of oxygen in the Sun. He accordingly made his ascent in winter, so that the influence of aqueous vapour in the atmosphere might be at a minimum. His observations negatived the existence of oxygen in the solar atmosphere, though recent observations are of a more positive character.

His unwearied activity throughout his life is shown by the numerous contributions to the *Comptes Rendus*, the *Annales de Chimie*, and many other scientific publications.

In 1873 Janssen was elected a member of the Académie des Sciences and the Bureau des Longitudes. In 1875 he became a Foreign Member of the Royal Society, who in 1877 gave him the Rumford Medal. The Academies of Rome, St Petersburg, Edinburgh, Brussels, and Washington did honour to him by electing him as one of their corresponding members.

A cold caught last December developed into congestion of the lungs, from which he died on the 23rd of that month, leaving a devoted wife and daughter to mourn the loss of one who will always rank as one of the most eminent scientific men of his country. He was elected an Associate 1872 Nov. 8. E. B. K.

MAURICE LOEWY was born of Jewish parents at Vienna on April 15, 1833. He was educated at the Polytechnic School and at the University of Vienna, and received his astronomical training at the Imperial Observatory under the directorship of von Littrow. His first contribution to astronomical literature is in the *Sitzungsberichte* of the Vienna Academy for April 16, 1857, and consists of a determination of the elements of the minor planet Leda then just discovered. Other computations of a similar character followed, including one of the elements of Donati's comet.